



LAUNCH OPERATIONS CENTER

23p

TR-4-13-2-D
July 15, 1963

OTS: #

mfs
N64-16706

Code 1

160776

John F. Kennedy Space
Center, Cocoa Beach, Fla.

(NASA TMX54645;

± SPECIALIZED COST STUDY,
LAUNCH COMPLEX 39—
PNEUMATIC SYSTEM

By

M. B. Loeb

15 Jul. 1963

23p *refs*

OTS PRICE

| | | |
|-----------|----|---------------|
| XEROX | \$ | <u>260.00</u> |
| MICROFILM | \$ | <u>.89</u> |

July 15, 1963

LAUNCH OPERATIONS CENTER

TR-4-13-2-D

SPECIALIZED COST STUDY, LAUNCH COMPLEX 39 -
PNEUMATIC SYSTEM

by M. B. Loeb

ABSTRACT

16706 A
This report presents the results of a specialized cost study upon which the decisions affecting design responsibilities of the LO-DP23 office concerning the conversion, compression, transmission, and high-pressure storage portions of the pneumatic system for Launch Complex 39 can be based.

The report covers cost responsibilities of the LO-DP23 office concerning pneumatic systems for conversion, transmission, and storage of gases at various pressures from 6000 psig to 10,000 psig. The report shows that the optimum conditions of design occur at 12,000, 10,000, and 7,400 psig, depending on the selection of materials used for the cross-country pipe. These optimum pressures are for systems with cross-country pipe materials of AISI 4320 steel with stainless liner, A106 Gr. C steel pipe with stainless liner, and type 316 stainless steel, respectively. These were the only pipe materials considered.

AUTHOR

LAUNCH OPERATIONS CENTER

TR-4-13-2-D

SPECIALIZED COST STUDY, LAUNCH COMPLEX 39 -
PNEUMATIC SYSTEM

by

M. B. Loeb

Prepared by:

PROPELLANT SYSTEMS BRANCH
LAUNCH SUPPORT EQUIPMENT ENGINEERING DIVISION

TABLE OF CONTENTS

| | Page No. |
|---|----------|
| Introduction | 1 |
| Description | 3 |
| Converters and Compressors | 3 |
| Converter-Compressor Facility Interconnecting Piping | 3 |
| Cross-country Transmission Piping | 4 |
| High-Pressure Storage Battery | 5 |
| Overall Costs | 5 |
| Conclusions | 6 |
| Recommendations | 7 |
| Appendix | 8 |

LIST OF ILLUSTRATIONS

| <u>Number</u> | <u>Title</u> |
|---------------|--|
| Fig. 1 | Composite Cost Chart, Pneumatic Systems, Cost Comparisons |
| Fig. 2 | Nitrogen Pipe Line I.D. Variations with Pressure |
| Fig. 3 | Nitrogen Pipe Wall Thickness Variations with Pressure |
| Fig. 4 | Helium Pipe Line I.D. Variations with Pressure |
| Fig. 5 | Helium Pipe Wall Thickness Variations with Pressure |
| Fig. 6 | Storage Vessel Costs |
| Fig. 7 | Optimum Storage Pressure |
| Fig. 8 | Optimum Storage Pressure |
| Fig. 9 | Comparison Costs |

DEFINITION OF TERMS

Converter: Mechanical pumping and vaporizing equipment used to convert liquid nitrogen to high-pressure gaseous nitrogen.

Compressor and Converter Interconnecting Piping: Includes all low-pressure type 316 stainless steel induction piping from the liquid nitrogen and gaseous helium storage to the converters and compressors; and the type 316 stainless steel high-pressure discharge piping from the converters and the compressors to the cross-country transmission piping.

Cross-country Transmission Piping: Piping used to transport high-pressure gaseous nitrogen and helium from the converter-compressor facility to the high-pressure battery storage facilities at the launch pads and the Vertical Assembly building.

Design Pressure: The system working pressure of the storage battery vessels.

Residual Storage Pressure: The lowest pressure of the storage battery vessels during a launch operation.

Operating Pressure: Any storage battery vessel pressure between design and residual pressure.

Water Volume Storage: The fixed vessel volume in cubic feet.

Unit Vessel Costs: The cost per cubic foot water volume of fabricated storage vessel.

Battery Interconnecting Piping and Manifolding: Includes all high-pressure piping from the cross-country transmission pipe systems interface to the storage battery vessels, the interconnecting piping and manifolding of the high-pressure gaseous nitrogen storage vessels and the high-pressure gaseous helium vessels, and the discharge piping from the nitrogen and helium storage vessels to the ground level interface at the Launcher Umbilical Transporter.

Primary Pressure Regulation System: The primary pressure regulation system, as it now exists, is connected between the high pressure gaseous helium and nitrogen ground interface at the LUT and the control panels on the LUT.

INTRODUCTION

The factors to be considered in the design of the pneumatic system for Launch Complex 39 are: availability of operating equipment, selection of materials, reliability, and the costs involved. Within the limits of operating possibilities, selection of available materials, available operating equipment, and other design variations, there are numerous possible designs. To establish a basis for sound economical design, within the assigned responsibility of LO-DP23, the various costs involved within the allowable limits of design were considered and the results tabulated for comparison. The primary pressure regulation of the pneumatic system has become the responsibility of LO-DP23 as a result of group meetings between LO-DP23 and LO-DE23 held during the preparation of this report.

The system was categorized as follows:

- a. Converters and compressors
- b. Converter/compressor interconnecting piping
- c. Cross-country transmission piping
- d. Battery storage vessels
- e. Battery interconnecting piping
- f. Primary pressure regulation

The pneumatic system consists of two separate gas handling systems: one for nitrogen, and one for helium. The nitrogen gas system requires pumps and vaporizers to convert liquid nitrogen to high-pressure gaseous nitrogen. The helium gas system requires the use of mechanical compression equipment to raise the pressure of gaseous helium from tube tank cars to the battery storage pressure.

In this report the variables of the above systems are considered separately at six incremental pressure steps. The resulting cost variations of each part of the system are charted. To establish overall costs, the costs of the individual parts of the system are combined.

The technical requirements of design and cost of electrical sub-station and power distribution, buildings and superstructures, concrete foundations and supports, specialized instrumentation, and the associated pneumatic systems operating at less than 6,000 psig are not considered in this report.

The costs are based on LO-DP23 estimates, manufacturers' surveys, and system cost comparisons. These estimates yield a high degree of accuracy for reviewing design decisions of cost differences specific to LO-DP23 responsibilities. The data furnished relate costs to specific specialized mechanical responsibilities of the LO-DP23 office and are intended to be informative for LO-DP23 review and review by others interested in this specialized design area.

DESCRIPTION

1. Converters and Compressors. The nitrogen converters are obtainable commercially as standard, complete, self-contained units capable of delivering 1,100 standard cubic feet per minute at 6,000 psig. The helium compressors are also standard, complete, self-contained commercial units that are capable of delivering 150 standard cubic feet per minute of helium at 6,000 psig. Both units will deliver gas from 6,000 to 10,000 psig. The efficiency of these units decreases as the discharge pressure requirements increases. The design flow rate of these units, as mentioned, in a minimum value considered constant within the discharge pressure range from 6,000 to 10,000 psig for design purposes. No allowance is provided for changes in capacity resulting from changes in efficiencies.

In each sub-system, the converters and compressors perform two functions: they furnish the initial pressurization of the storage battery vessels, and they replenish the vessels during operation to maintain operating pressure during peak demands. In this report, the replenish rate determines the number of converters and compressors. The replenish rate requirement in standard cubic feet per minute is independent of pressure and is constant regardless of the pneumatic system design pressure. Therefore, the same basic number of compressor units and converter units are required regardless of the system design pressure.

Based on the replenish rate required, four operating helium compressors and one spare totalling \$140,000, and five operating liquid nitrogen converters and one spare totalling \$400,000 are required. The total cost is \$540,000. (See figure 1, column 7.)

2. Converter-compressor Facility Interconnecting Piping. Piping for the converter-compressor facility consists of low-pressure type 316 stainless steel induction piping and high-pressure type 316 stainless steel discharge piping. The greater portion of the piping in this area is low-pressure induction piping. The induction piping design remains the same regardless of the high-pressure gas system design pressure. The high-pressure discharge piping designed for 6,000 psig with 4/1 safety factor based on ultimate strength is also suitable for pressures to 7,500 psig with 3/1 safety factor based on ultimate strength. Discharge piping designed for 8,000 psig is also suitable for pressures to 10,000 psig. It is estimated that the cost increase in the discharge piping system for pressures above 7,500 psig is \$12,500. The estimated costs of the converter-compressor facility piping are shown in figure 1, column 8.

3. Cross-country Transmission Piping. Based on environmental conditions, pressures, cleanliness levels, availability, material costs, installation requirements, and other system requirements, three materials for the cross-country piping were considered, and their costs estimated. These materials and assumptions made are:

a. AISI 4320 steel pipe with stainless liner, 3:1 safety factor based on ultimate strength of 93,950 psi (2:1 on yield).

b. A106 Grade C steel pipe with stainless liner, 3.5:1 safety factor based on ultimate strength of 70,000 psi. A106, Grade C steel conforms to ASTM Specification A-106-61T. (2:1 on yield).

c. Type 316 stainless steel pipe, 3.5:1 safety factor based on ultimate strength of 74,900 psi. This piping material conforms to ASTM Specification A-312-61T (2:1 on yield)

The following additional assumptions were made:

a. The pressure drop in the cross-country piping system will not exceed 10 percent of the converter-compressor facility delivery pressure at the most remote part of the system while delivering the unrestricted full replenish rate.

b. The most remote part of the cross-country piping system, for pressure drop calculation purposes, is the Pad C storage battery interface.

c. One inside diameter requirement for the piping can be selected which can meet the capacity requirements as a minimum delivery guarantee. All design pressures within the range of 6,000 to 10,000 psig will deliver full unrestricted replenish rate or more with 10 percent or less pressure drop within the system.

The determination of inside diameter requirements for the cross-country lines is presented in chart form. (See figure 2 for GN₂ system and figure 4 for GHe system.)

Pipe inside diameter requirements were determined to be 2-1/2 inches for nitrogen piping system and 1 inch for helium piping system. Based on these sizes, the wall thickness requirements were determined at various design pressures from 6,000 psi to 10,000 psi. The wall thicknesses are shown in figures 3 and 5. Using inside diameter and wall thickness data, unit prices were obtained corresponding to the various system design pressures. The lengths of pipe and total piping system costs at specific pressures and with the three materials are shown in figure 1, columns 12, 13, 14 and 15.

4. High-Pressure Storage Battery. The Propellant Systems Branch has made a survey of pressure vessel costs per cubic foot of water volume as related to vessel design pressure. Results of this survey are shown in figure 6. Selected unit costs based on the chart in figure 6 are shown in figure 1, column 3.

A minimum, or residual, pressure of 4,000 psig remains in the battery after use. This residual pressure is correlated with design pressure, volumetric storage efficiency, and unit costs in determining optimum storage battery pressure. (See figure 7). The effect of design pressure on storage efficiency can be compared in figure 1, columns 1 and 2. Total vessel costs can be obtained from the volume requirements and the vessel unit costs. (See figure 1, column 4.)

The costs of the interconnecting battery piping at six pressures were prepared from suppliers' prices and office estimates. The results are shown in figure 1, column 6.

5. Overall Costs. The overall costs for Pad A at the six assumed pressures are shown in figure 1, column 16. These costs are shown for each of the three materials considered for the cross-country piping. Overall costs for Pads B and C and the VAB are shown in figure 1, columns 17, 18 and 19, respectively. The cost for Pad A includes the converter-compressor facility. Cost of the converter-compressor facility is not included in the total cost of Pads B, C, and the VAB pneumatic system, because one converter-compressor facility supplies all pads and the VAB.

The total system cost for all three pads and the VAB combined is shown in figure 1, column 20.

The optimum design pressure in relation to total costs for each cross-country line material is shown graphically in figure 9.

CONCLUSIONS

1. The lowest costs for the system result when pneumatic system design pressures are 12,000 psig, 10,000 psig, and 7,400 psig, using 4320 steel, A-106 steel, and type 316 stainless steel, respectively, as cross-country pipe line material. (See figure 9).

2. The lowest costs for storage vessels result with a design storage pressure of 9,700 psig for gaseous nitrogen and 11,500 psig for gaseous helium. (See figure 7).

3. Costs of the following decrease with increase in design pressure:

a. Total storage vessel battery (see figure 1, column 4).

b. Battery interconnecting piping and manifolding (see figure 1, column 6).

4. The cost of converter and compressor equipment remains constant regardless of pressure within the range of 6,000 to 10,000 psig (See figure 1, column 7).

5. The cost of cross-country pipe lines increases with increases in design pressure (see figure 1, columns 12, 13, 14 and 15).

6. The volumetric storage efficiency of the storage battery increases with increases in design pressure, resulting in lowered battery costs and smaller required storage area at higher pressures (see figure 1, column 5).

RECOMMENDATIONS

1. It is recommended that the existing high-pressure (7,500 to 10,000 psig) test and evaluation programs be continued so that high-pressure pneumatic systems can be designed to realize the cost savings possible at the higher pressures. This program is expected to furnish the necessary information on pressure regulators, and AISI 4320 steel for field constructed pipe lines.

2. It is recommended that ASTM A-106-61T, Grade C steel pipe, mechanically coupled, with a Series 300 steel liner, be used in the design of Launch Complex 39 cross-country piping. A system design pressure of 7,500 psig is recommended to realize cost savings when the programs of paragraph number one are satisfactorily concluded. This recommendation is contingent upon scheduling which affects cost.

3. It is recommended that the operating pressure of the LC 39 pneumatic system be 6,000 psig until the test programs are satisfactorily concluded.

4. It is recommended that the primary pressure regulation equipment be physically located between the storage battery and the ground level interface at the Launcher/Umbilical Transporter.

APPENDIX

Various manufacturers and governmental agencies which operate high pressure systems were contacted to determine the existence and reliability of various operating equipment within the range of 6,000 and 10,000 pounds per square inch. A sampling of the various organizations contacted are listed below. The number appearing in parentheses represents the operating pressures in pounds per square inch gage being used by them in continuous service duty.

1. Hercules Powder Company (15,000) Louisiana, Missouri gaseous nitrogen and hydrogen service.
2. DuPont de Nemours and Co. (15,000) Belle, West Virginia gaseous nitrogen and hydrogen service.
3. Mississippi Chemical Company (15,000) Yazoo City, Mississippi gaseous nitrogen and hydrogen service.
4. W. R. Grace Company (12,500) Memphis, Tennessee gaseous nitrogen and hydrogen service.
5. Cooperative Farm Chemical Association (12,000) Lawrence, Kansas gaseous nitrogen and hydrogen service.
6. John Deere (12,000) Pryor, Oklahoma gaseous nitrogen and hydrogen service.
7. Big Three Welding Company (7,500) Houston, Texas liquid and gaseous nitrogen.
8. Nitro-Well Incorporated (7,500 and 10,000) liquid and gaseous nitrogen.

This list is for reference purposes only and does not include all known systems.

From the above references it has been determined that systems and component parts of systems are presently being manufactured and used in comparable systems to the systems represented in this report.

The following technical publications were used as basic reference material:

1. "Saturn C-5 Pneumatics Handling Preliminary Criteria" ER13561 dated August 1, 1962, Contract NAS10-33 by Beech Aircraft Corporation, Boulder Division, P. O. Box 631, Boulder, Colorado.

2. "A compendium of the Properties of Materials at Low Temperature" (Phase I and II).

WADD Technical Report 60-58 by Aeronautical Systems Division, Air Force Systems Command, United States Air Force, Wright-Patterson Air Force Base, Ohio.

3. "Design Handbook for Liquid and Gaseous Helium Handling Equipment". ASD Technical Report 61-226 Aeronautical Systems Division, Air Force Systems Command, United States Air Force, Wright-Patterson Air Force Base, Ohio.

4. "Physical and Thermodynamics Properties of Helium" by Whittaker Controls Division of Telecomputing Corporation 1957.

5. "Thermodynamic and Transport Properties of Helium", by W. P. Wilson, Jr. for Electric Boat Division of General Dynamics Corporation, January 1960.

6. "Thermodynamic Properties of Nitrogen" Research Bulletin 18 by Institute of Gas Technology, October 1952.

7. "Flow of Fluids through Valves, Fittings and Pipe" Crane Technical Paper No. 410, Crane Company, 836 S. Michigan Avenue, Chicago, Illinois.

APPROVAL

TR-4-13-2-D

SPECIALIZED COST STUDY
LAUNCH COMPLEX 39
PNEUMATIC SYSTEM

ORIGINATOR:

Marx B. Loeb 10/3/63
Marx B. Loeb
Mechanical Section

APPROVALS:

Carl D. Lamb 10/8/63
Carl D. Lamb
Mechanical Section

Charles R. Minton
Charles R. Minton
Chief, Mechanical Section

Chester T. Wasileski
Chester T. Wasileski
Chief, Propellant Systems Branch

Theodor A. Poppel
Theodor A. Poppel
Director, Launch Support Equipment
Engineering Division

BATTERY & CONV/COMP FAC. COSTS.

NOTES

BATTERY AND C/C FACILITY
PIPING, FITTINGS, ETC.
ARE ALL S/S TYPE 316.

COLUMN 16 = COLUMN 10 + COLUMN 12
" 17 = " 11 + " 13
" 18 = " 11 + " 14
" 19 = " 11 + " 15
" 20 = COL. 16 + COL. 17 + COL. 18 + COL. 19
COL. 11 = COL. 4 + COL. 6
COL. 10 = COL. 7 + COL. 8 + COL. 9 + COL. 11

| BATTERY PRESS RANGE, (PSI) | STORAGE REQMTS (FT ³) | | UNIT VESSEL COST (\$/FT ³) | TOTAL VESSEL COST (\$) | REQD PAD AREA FOR STORAGE (FT ²) | BATTERY PIPING COSTS (\$) | PUMPING EQUIP. COST (\$) | CONV./COMP PIPING COST (\$) | TESTING & EVAL. COST (\$) | TOTAL BATT. & C/C FAC. COST (\$) | TOTAL BATTERY COST (\$) |
|----------------------------------|-----------------------------------|---------------------------------|--|------------------------------|--|---------------------------------|--------------------------------|-----------------------------------|---------------------------------|--|-------------------------------|
| | 16913 AVAIL. #GN ₂ | 9468 AVAIL. #GN ₂ | | | | | | | | | |
| 10,000 - 4000 | 1286 | 3220 | 148 | 666,888 | 1706 | 156,474 | 540,000 | 162,500 | 120,000 | 1,645,862 | 823,362 |
| 9,000 - 4000 | 1470 | 3864 | 131 | 698,754 | 2014 | 163,760 | 540,000 | 162,500 | 120,000 | 1,685,014 | 862,514 |
| 8,000 - 4000 | 1735 | 4664 | 114 | 729,486 | 2419 | 172,664 | 540,000 | 162,500 | 120,000 | 1,724,650 | 902,150 |
| 7,500 - 4000 | 1911 | 5289 | 106 | 763,200 | 2722 | 181,222 | 540,000 | 150,000 | 120,000 | 1,754,422 | 944,422 |
| 7,000 - 4000 | 2114 | 6148 | 98 | 809,676 | 3121 | 193,427 | 540,000 | 150,000 | 120,000 | 1,813,103 | 1,003,103 |
| 6,000 - 4000 | 2941 | 8767 | 83 | 971,764 | 4427 | 189,370 | 540,000 | 150,000 | 10,000 | 1,861,134 | 1,161,134 |

GROSS COUNTRY TRANSMISSION PIPING COSTS

| BATTERY PRESS. RANGE (PSI) | X-COUNTRY PIPING TO PAD A | | X-COUNTRY PIPING TO PAD B | X-COUNTRY PIPING TO PAD C | X-COUNTRY PIPING TO VAB |
|----------------------------------|--|-----------------------|---------------------------|--|-------------------------|
| | 13,000' 2 1/2" I.D. (GN ₂) | 13,000' 1" I.D. (GHe) | 11,500' 1" I.D. (GHe) | 17,500' 2 1/2" I.D. (GN ₂) | 5500' 1" I.D. (GHe) |
| 10,000 - 4000 | 717,470 | 815,490 | 1,430,260 | 1,430,260 | 605,110 |
| 9,000 - 4000 | 703,950 | 785,200 | 1,220,960 | 1,220,960 | 516,560 |
| 8,000 - 4000 | 691,340 | 758,680 | 1,092,780 | 1,092,780 | 462,330 |
| 7,500 - 4000 | 683,475 | 732,810 | 1,036,230 | 1,036,230 | 438,405 |
| 7,000 - 4000 | 675,610 | 706,940 | 979,680 | 979,680 | 414,480 |
| 6,000 - 4000 | 644,670 | 667,680 | 880,100 | 880,100 | 372,350 |

UNIT COST PER PAD AND CUMULATED TOTALS FOR THREE PADS & VAB

| BATTERY PRESS. RANGE (PSI) | TOTAL COST PAD A | | TOTAL COST PAD B | TOTAL COST PAD C | TOTAL COST VAB | GRAND TOTAL | |
|----------------------------------|------------------|-----------|------------------|------------------|----------------|-------------|-----------|
| | 4320 | A106 | 4320 | A106 | 4320 | A106 | S/S |
| 10,000 - 4000 | 2,363,332 | 2,461,352 | 3,076,122 | 3,076,122 | 1,428,472 | 6,737,473 | 7,095,623 |
| 9,000 - 4000 | 2,388,964 | 2,470,214 | 2,905,974 | 2,905,974 | 1,379,074 | 6,844,681 | 7,141,416 |
| 8,000 - 4000 | 2,415,990 | 2,483,330 | 2,817,430 | 2,817,430 | 1,364,480 | 6,957,150 | 7,203,030 |
| 7,500 - 4000 | 2,437,897 | 2,487,232 | 2,790,652 | 2,790,652 | 1,382,827 | 7,084,999 | 7,265,178 |
| 7,000 - 4000 | 2,488,713 | 2,520,043 | 2,792,783 | 2,792,783 | 1,417,583 | 7,290,587 | 7,405,462 |
| 6,000 - 4000 | 2,505,804 | 2,528,814 | 2,741,234 | 2,741,234 | 1,533,484 | 7,700,061 | 7,784,136 |

(A) 4 HELIUM COMPRESSORS + 1 SPARE @ \$28000 EA. & 5 LN₂ CONVERTERS + 1 SPARE @ \$66,666 EA.

| | | | | | |
|-----------------------------|--|-----------------------------|--|-------------------------------------|-----------|
| SEE ENGINEERING RECORDS | | UNLESS OTHERWISE SPECIFIED | | ORIGINAL DATE OF DRAWING 10 MAY '63 | |
| DIMENSIONS ARE IN INCHES | | TOLERANCES ON FRACTIONS N/A | | DRAFTSMAN PB | CHECKER |
| DECIMALS N/A | | ANGLES N/A | | CHECKER | |
| MATERIAL N/A | | HEAT TREATMENT N/A | | ENGINEER | SUBMITTED |
| FINAL PROTECTIVE FINISH N/A | | APPROVED | | ENGINEER | |
| NEXT ASSY | | USED ON | | DATE | CODE |
| APPLICATION | | APPROVED | | SCALE N/A | |

FIG. 1

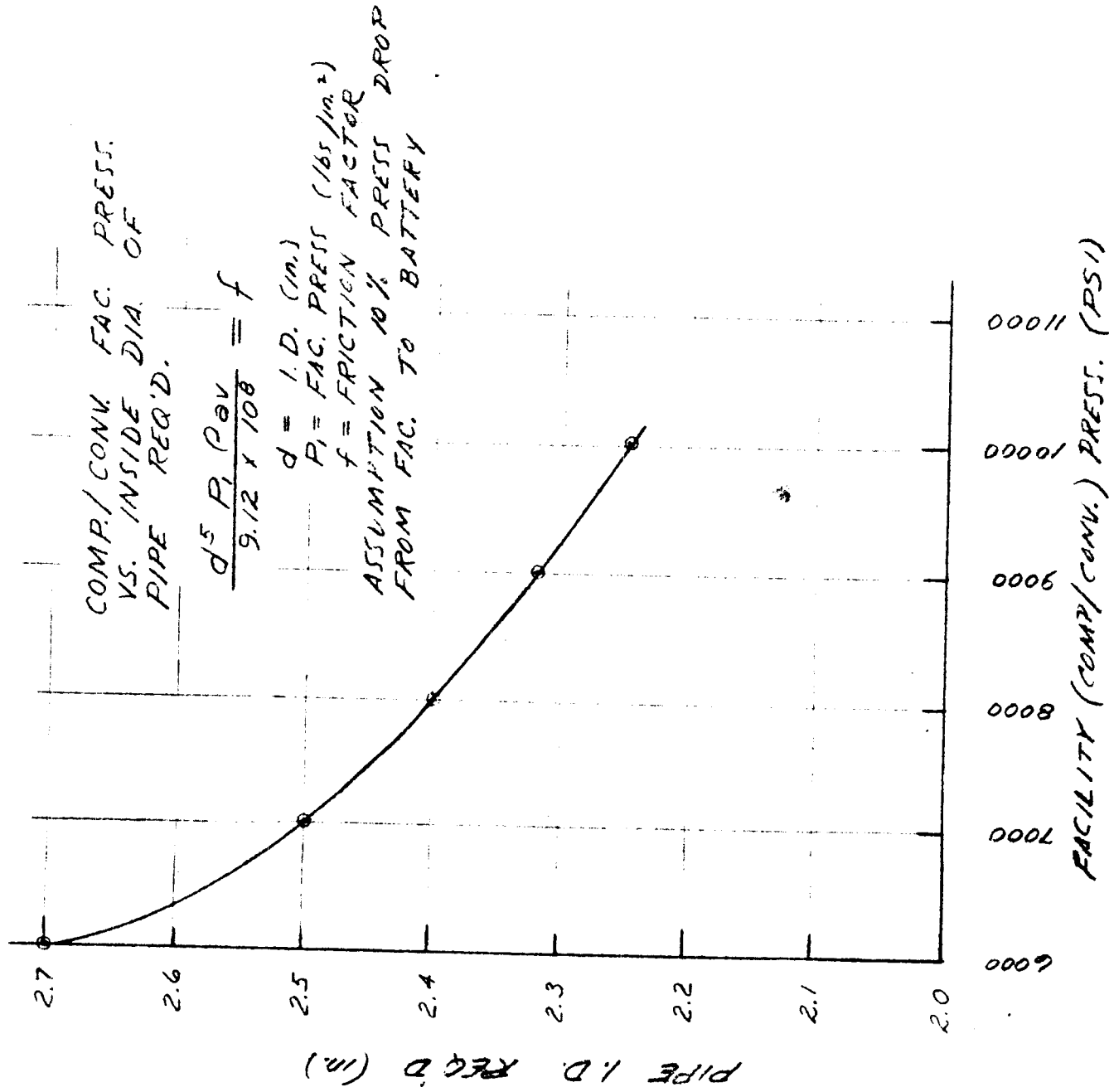
COMPOSITE COST CHART

PNEUMATIC SYSTEMS

COST COMPARISONS

| | | |
|---|--|------------|
| GEORGE C. MARSHALL SPACE FLIGHT CENTER | | DWG SIZE B |
| NATIONAL AERONAUTICS AND SPACE ADMINISTRATION | | |
| HUNTSVILLE, ALABAMA | | |

procurement operation, the United States Government is not responsible for any obligation whatsoever and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications or other data is not to be regarded as an assumption of liability on the part of the Government for any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.



REVISIONS

| ZONE | SYM | DESCRIPTION | DATE | APPROVAL |
|------|-----|-------------|------|----------|
| | | | | |
| | | | | |
| | | | | |

| | | | |
|----------------------------|--|----------------------------------|--|
| UNLESS OTHERWISE SPECIFIED | | ORIGINAL DATE OF DRAWING 5/10/63 | |
| DIMENSIONS ARE IN INCHES | | DRAWN BY | |
| TOLERANCES ON | | CHECKER | |
| FRACTIONS | | STRESS | |
| DECIMALS | | ENGINEER | |
| ANGLES | | SUBMITTED | |
| MATERIAL | | APPROVED | |
| HEAT TREATMENT | | DIRECTOR | |
| FINAL PROTECTIVE FINISH | | | |
| SEE ENGINEERING RECORDS | | | |
| NEXT ASSY | | USED ON | |
| APPLICATION | | | |
| | | WEIGHT CHECKER | |
| | | DATE | |
| | | CODE | |
| | | UNIT WEIGHT | |
| | | SCALE | |
| | | SHEET | |
| | | OF | |

| | |
|------------|---|
| DISTR CODE | GEORGE C. MARSHALL SPACE FLIGHT CENTER |
| | NATIONAL AERONAUTICS AND SPACE ADMINISTRATION |
| | HUNTSVILLE, ALABAMA |
| DWG SIZE | B |
| SHEET | |
| OF | |

FIG. 2
NITROGEN PIPE LINE
I.D. VARIATIONS WITH
PRESSURE

PROVISIONS

COMP/CONV. FAC. PRESS. VS.
TUBE WALL THK. IN INS.
FOR STAINLESS, TYPE 316;
A106 GR "C" STL; & A320
STL.

$$Z = \frac{PR}{S - 0.6P} + 0.05$$

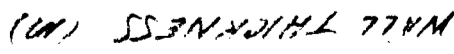
$$S = \text{ALLOWABLE WORKING STRESS (PSI)}$$

$$21400 \text{ PSI FOR STAINLESS}$$

$$20000 \text{ PSI FOR A-106 GR"C"}$$

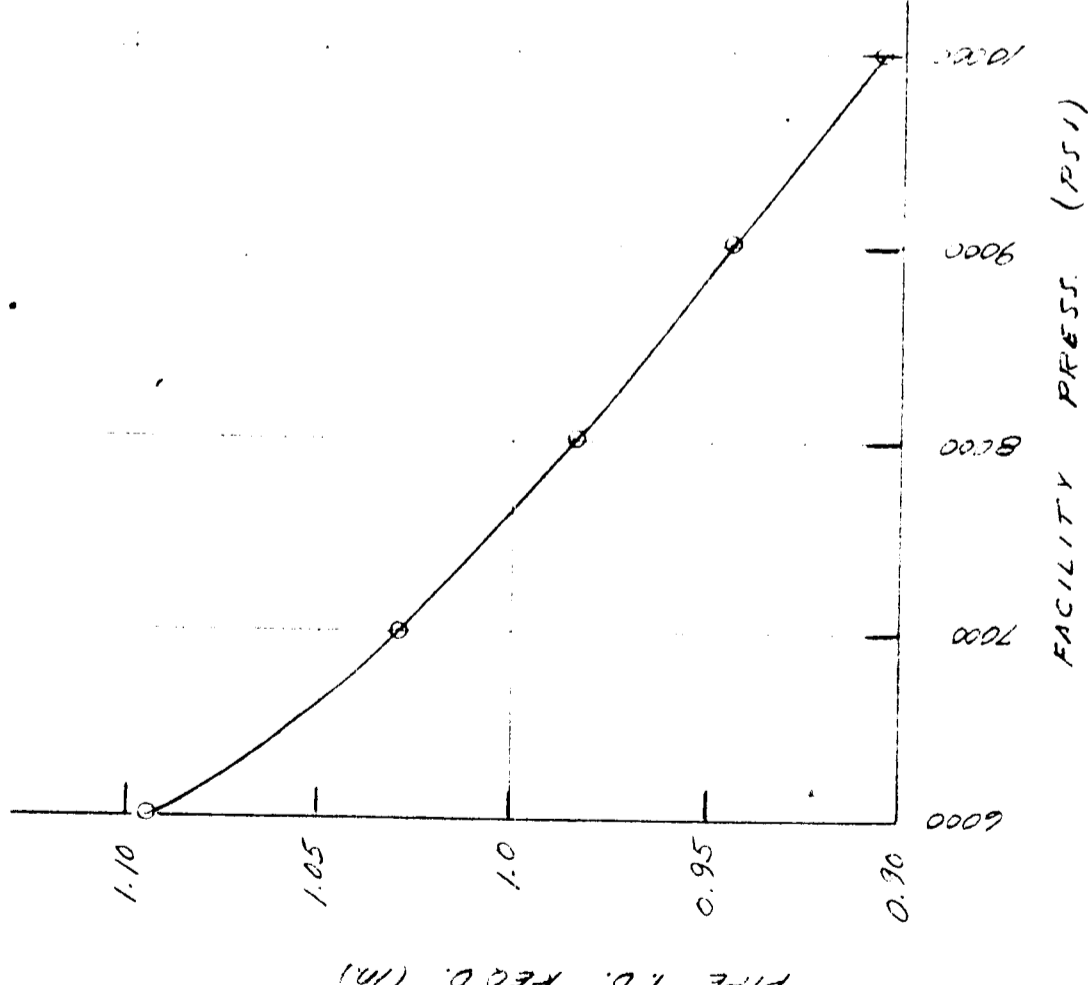
$$31650 \text{ PSI FOR 4320 STL.}$$

P = FAC. PRESS (PSI)
t = TUBE WALL THICKNESS (IN.)
R = TUBE RADIUS (INS.) = 1.25"

[illegible]

Notes - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

| PART NO. | | REVISONS | |
|----------|--|-------------|--|
| M F | | DESCRIPTION | |
| ZONE | | DATE | |
| SYM | | APPROVAL | |



COMP/CONV. FAC. PRESS
VS. INSIDE DIA. OF
PIPE REQ'D.

$d^5 P_1 \rho g v$
 $1.36 \times 10^5 = f$

$d = 1.0$ (in.)
 $P_1 = \text{FAC. PRESS.}$
 $f = \text{FRICTION FAC.}$

ASSUMPTION: 10% PRESS.
DROP FROM FAC. TO
BATTERY.

| | | | | | | | |
|----------------------------|--|-------------------------------------|--|-----------------------|--|--------------------------|--|
| UNLESS OTHERWISE SPECIFIED | | ORIGINAL DATE OF DRAWING 5/10/63 | | FIG. 4 | | DISTR CODE | |
| DIMENSIONS ARE IN INCHES | | DRAWING | | HELIUM PIPE LINE I.D. | | GEORGE C. MARSHALL | |
| TOLERANCES ON | | CHECKER | | VARIATIONS WITH | | SPACE FLIGHT CENTER | |
| FRACTIONS | | STRESS | | PRESSURE | | NATIONAL AERONAUTICS | |
| DECIMALS | | ENGINEER | | WEIGHT CHECKER | | AND SPACE ADMINISTRATION | |
| ANGLES | | SUBMITTED | | DATE | | HUNTSVILLE, ALABAMA | |
| MATERIAL | | APPROVED | | CODE | | DWG SIZE | |
| HEAT TREATMENT | | DIRECTOR | | UNIT WEIGHT | | B | |
| FINAL PROTECTIVE FINISH | | SCALE | | SHEET | | OF | |
| NEXT ASSY | | USED ON | | APPLICATION | | | |
| APPLICATION | | | | | | | |

Notice — When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

COMP / CONV. FAC. PRESS VS. TUBE WALL THK. IN INS. FOR STAINLESS STEEL TYPE 316, A-106 GR" C" STL.; & A320 STL.

$$t = \frac{S - 0.6P}{PR} + 0.05$$

S = ALLOWABLE WORKING STRESS

21400 PSI FOR STAINLESS

20000 PSI FOR A-106 GR" C"

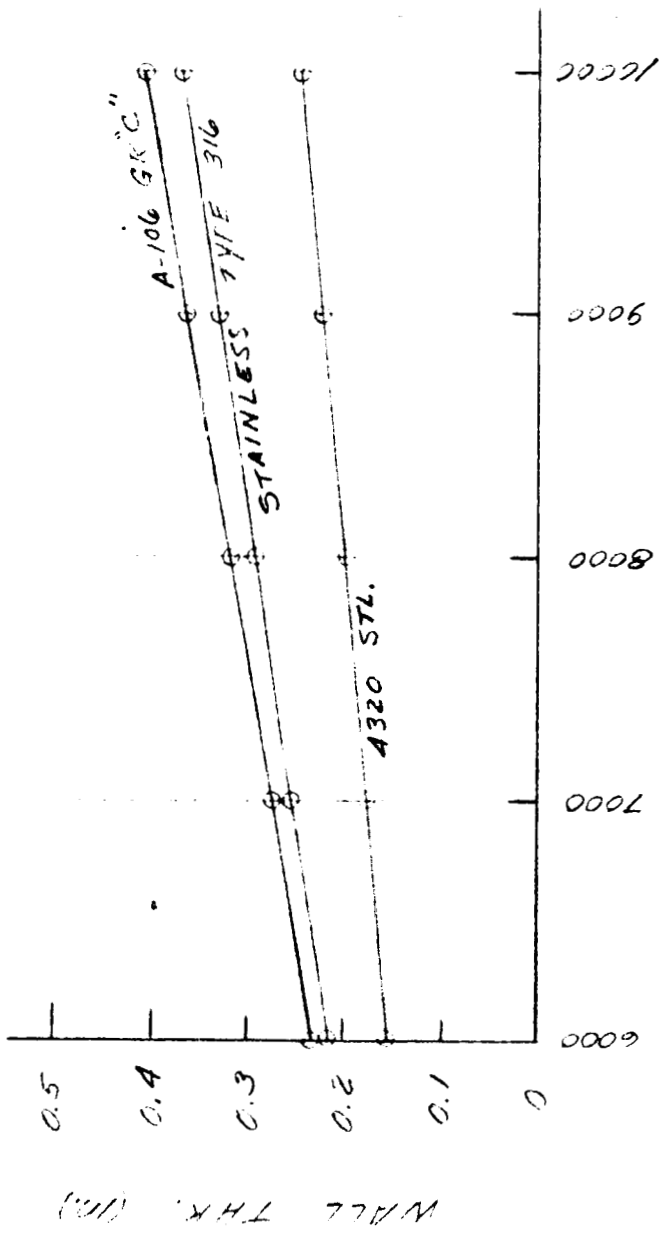
31650 PSI FOR A320 STL.

P = FACILITY PRESS. (PSI)

t = TUBE WALL THK. (IN.)

R = RADIUS (INSIDE) = 5.5 in.

SAFETY FACTORS
1) 3.5 1 FOR A-106
GR" C" & STAINLESS
BASED ON ULTIMATE.
2) 3.1 FOR A320 STL.
BASED ON ULTIMATE.



FAC. PRESS. (PSI)

PART NO. MF

REVISIONS

DESCRIPTION

DATE

APPROVAL

ZONE

SYM

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

APPROVAL

DATE

| | |
|------------|--|
| DISTR CODE | GEORGE C. MARSHALL SPACE FLIGHT CENTER NATIONAL AERONAUTICS AND SPACE ADMINISTRATION HUNTSVILLE, ALABAMA |
| DWG SIZE | B |
| SHEET | OF |

| | | |
|----------------|--|------|
| FIG. 5 | HELIUM PIPE WALL THK. VARIATIONS WITH PRESS. | |
| WEIGHT CHECKER | DATE | CODE |
| SCALE | UNIT WEIGHT | |

| | |
|--------------------------|----------|
| ORIGINAL DATE OF DRAWING | 5/10/63 |
| DRAFTSMAN | CHECKER |
| CHECKER | STRESS |
| ENGINEER | ENGINEER |
| SUBMITTED | |
| APPROVED | DIRECTOR |

| | | | | |
|----------------------------|--------------------------|-------------------------|----------|--------|
| UNLESS OTHERWISE SPECIFIED | DIMENSIONS ARE IN INCHES | TOLERANCES ON FRACTIONS | DECIMALS | ANGLES |
| SEE ENGINEERING RECORDS | | | | |
| NEXT ASSY | USED ON | | | |
| APPLICATION | | | | |

| | |
|-------------------------|--|
| MATERIAL | |
| HEAT TREATMENT | |
| FINAL PROTECTIVE FINISH | |

UNIT COST/16. AVAILABLE GAS (in #)



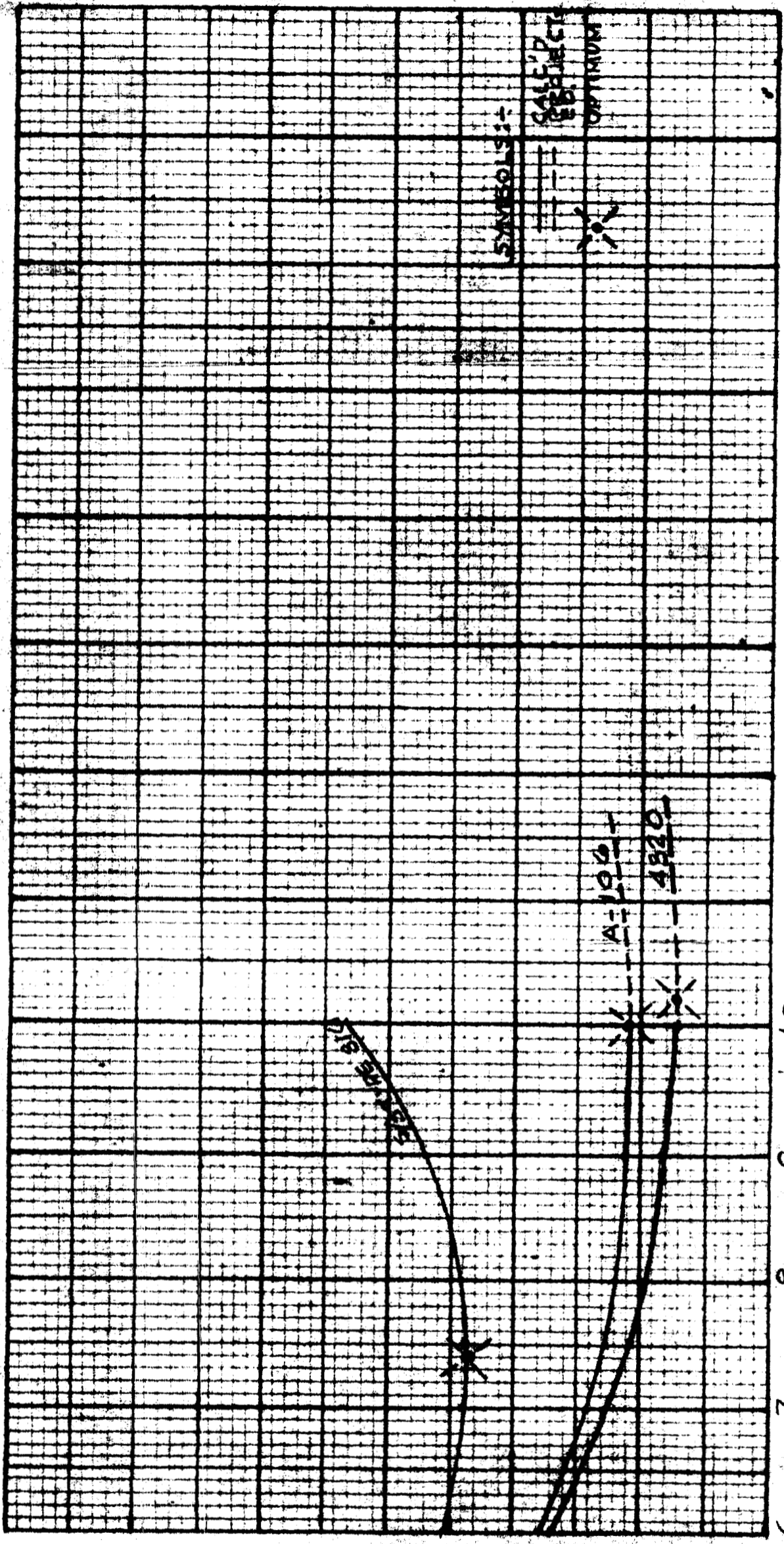
| | |
|-----------------------------|----------|
| ORIGINAL DATE OF DRAWING | 3/4/63 |
| DRAFTSMAN | CHECKER |
| CHECKER | STRESS |
| ENGINEER | ENGINEER |
| APPROVED | |

| | | | |
|------------|--|-------------------------|-------------|
| DISTR CODE | GEORGE C. MARSHALL SPACE FLIGHT CENTER NATIONAL AERONAUTICS AND SPACE ADMINISTRATION HUNTSVILLE, ALABAMA | DWG SIZE B | SHEET OF |
|------------|--|-------------------------|-------------|

[illegible]

preparation, operation, the United States Government hereby disclaims any responsibility for any errors or omissions in this drawing. The Government may have furnished, furnished or to be supplied by the Government, the services or other data in part to be supplied by the Government or contractor. In any instance, including the design or any other form or representation, it is the responsibility of the contractor to ensure that they in any way be reliable.

| PART NO. | | REVISIONS | |
|----------|--|-------------|----------|
| N° | | DESCRIPTION | DATE |
| ZONE | | SYM | APPROVAL |



| | | | | | | | | | |
|-------------------------|--|----------------------------|--|---------------------------------------|--|--|--|---------------------------------------|--|
| SEE ENGINEERING RECORDS | | UNLESS OTHERWISE SPECIFIED | | ORIGINAL DATE OF DRAWING MAY 28, 1963 | | GEORGE C. MARSHALL SPACE FLIGHT CENTER NATIONAL AERONAUTICS AND SPACE ADMINISTRATION HUNTSVILLE, ALABAMA | | DWG SIZE B | |
| NEXT ASSY | | DIMENSIONS ARE IN INCHES | | DRAWN BY | | FIG 9 | | COMPARISON COSTS (REF. FIG 1 COL. 20) | |
| USED ON | | TOLERANCES ON | | CHECKER | | DATE | | WEIGHT CHECKER | |
| APPLICATION | | FRACTIONS | | ENGINEER | | CODE | | SCALE | |
| | | DECIMALS | | SUBMITTED | | UNIT WEIGHT | | | |
| | | ANGLES | | APPROVED | | | | | |
| | | MATERIAL | | DIRECTOR | | | | | |
| | | NEXT TREATMENT | | | | | | | |
| | | FINAL PROTECTIVE FINISH | | | | | | | |